conveying a current in a magnetic field is certainly more or less strained by mechanical forces, and hence heat will be developed unequally in different parts, by a sort of Peltier effect; and the result of this will be to modify the resistance in patches and so to produce a disturbance of the flow which may easily result partly in a transverse E.M.F. This has been pointed out by Mr. Shelford Bidwell.

The more direct effect of magnetism on conductivity may be negligibly small in many metals, but in bismuth it is certainly large. Both of these spurious effects seem to be large in bismuth, and probably quite mask any true Hall effect there may be in that metal. In all cases the existence of these spurious effects makes it difficult to be sure of the magnitude and sign of the real rotational effect.

But, it may be asked, what right have we to distinguish between a real and a spurious Hall effect? If a transverse E.M.F. can be predicted by reason of known strains and thermo-electric properties, as well as by known rotation of light effects, why should the two things be considered different? Why should they not be different modes of regarding one and the same phenomenon?

In other words, may not the Faraday rotation of light vibration be due to infinitesimal temporary strains and heatings in the medium caused by the fact that minute electric displacements are occurring in a violent magnetic field? This is a question capable of being answered by a quantitative determination of the amounts and direction of the effects to be expected, and a comparison with those actually observed. I do not know of data at present obtained sufficient to enable us to answer it. If the answer should turn out to be in the affirmative, the phenomenon of hysteresis will be at once linked, by an underground path, with those of thermo-electricity and strain.[1]

OLIVER J. LODGE.

*(To be continued.)*

## IRREGULAR STAR CLUSTERS.

IT is not always easy to distinguish between a casual "sprinkle" of stars and a genuine cluster. The movement-test, by which so many physical have been discriminated from optical double stars, is here inapplicable. The Pleiades are the only considerable group possessing an ascertained common proper motion. All other clusters, debarred as yet from the appeal to this demonstrative argument of their physical nature, have to depend solely upon evidence from probability, with its indefinite variations of conclusiveness according to the circumstances of each particular case. It is, however, in general, amply sufficient. Among five hundred clusters registered as such, there are few indeed as to which there can be any doubt of their forming separate systems; although many real aggregations may exist unrecognized, owing to their loosely scattered character.

Two inferences may be safely derived from the results of recent inquiries into the constitution of the Pleiades. First, that interstitial movements in clusters are likely to be so extremely slow that centuries must elapse before they can become conspicuous; next, that stars showing somewhat marked displacements are presumably mere travellers across, and no genuine components of, the cluster they seem to belong to. An example of this kind of temporary association is almost certainly furnished by an apparent member of a scattered group in Ophiuchus ("Gen. Cat." 1440), the position of which was found, by the comparison of photographs taken by M. von Gothard in 1886 with Vogel's measures of eighteen years previously, to have changed to the extent of $45''$, or at the rate of $2\frac{1}{2}''$ annually (*Astr. Nach.*, No. 2777). Its motion, if rectilinear, would carry it from end to end of the collection it is projected upon, in 360 years; and its eventual detachment from it may have become palpably inevitable within ten. The star is of the eleventh magnitude, and is by far the swiftest-moving yet known of so small a size.

Several of the stellar gems surrounding κ Crucis are suspected of considerable mobility. Sir John Herschel, during his visit to the Cape, determined the relative places of 110, all included in an area of about $\frac{1}{48}$ of a square degree ("Cape Observations," p. 17); and the process was, by Mr. H. C. Russell, of Sydney, in 1872, repeated and extended to 130 components (*Monthly Notices*, vol. xxxiii. p. 66). The result was to bring out discrepancies which, if really due to movements of the grouped stars, would be of extreme interest. Herschel's measurements, however, were necessarily too hasty to be minutely reliable; so that changes depending upon their authority need to be confirmed by continuance before they can be unreservedly accepted. The same qualification applies to M. Cruls's discovery of orbital revolution in three double stars within the precincts of the cluster (*Comptes rendus*, t. lxxxix. p. 435).

The stars about κ Crucis are famous for the loveliness of their varied hues. Blue and green, red and sulphur-coloured orbs shine together in a matchless sidereal picture, setting at the same time a problem in sidereal chromatics by no means easy to solve. There is no evidence of change of tint among them since Herschel's time, but there is some, tolerably conclusive, as to change of brightness.

Many irregular clusters seem to be throughout made up of star-streams and reticulations exactly similar to the inflected appendages of globular clusters. A collection (M 24) visible to the naked eye as a dim cloudlet near μ Sagittarii, and regarded by Sir John Herschel as intimately connected with, if not an actual part of, the Milky Way, was named by Father Secchi "Delle Caustiche," from the peculiar arrangement of its stars in rays, arches, caustic curves, and intertwined spirals. Closely adjacent to it, he noted a group of eleventh magnitude stars forming three spokes, as it were, and the nave of a wheel, the axis of which was occupied by a much brighter close pair (*Atti dell' Accad. Pont.*, t. vii. p. 72).

The same kind of radiated structure is apparent in a stellar swarm near the right foot of Castor (M 35), which, with Lassell's 24-inch mirror, showed as so "marvellously striking an object that no one could see it for the first time without an exclamation." A field $19'$ in diameter "is perfectly full of brilliant stars, unusually equal in magnitude and distribution over the whole area. Nothing but a sight of the object itself can convey an adequate idea of its exquisite beauty" (*Monthly Notices*, vol. xiv. p. 76). Admiral Smyth described it as "a gorgeous field of stars from the ninth to the sixteenth magnitudes, but with the centre of the mass less rich than the rest. From the small stars being inclined to form curves of three or four, and often with a large one at the root of the curve, it somewhat reminds one of the bursting of a sky-rocket" ("Cycle of Celestial Objects," p. 168, Chambers). A marvellously perfect photograph of this cluster, taken by the MM. Henry, March 10, 1886, exhibits not less than two thousand stars disposed in a roughly-indicated, eight-rayed figure, the branches often connected by drooping chains, and composed in detail of sinuous lines, or "fantastically crossing arcs" of stars (Secchi, *loc. cit.*).

About one hundred connected stars in Ophiuchus ("G. C." 4346) "run in lines and arches" (J. Herschel, Phil. Trans., vol. cxxiii. p. 460); a collection of eleventh magnitude ones in Sagittarius ("G. C." 4323) are scattered along "zigzag lines." The constituents of a large cluster near the Poop of Argo ("G. C." 1649) struck the elder

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[1] Perhaps I ought to caution students not to accept my connection of Faraday's or Hall's effect with hysterēsis as in any way authoritative. Until these views have been criticized it will be wise to place no reliance on them.

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Herschel by their arrangement "chiefly in rows," by which he gained some insight into the mechanical complexities of such systems. Each row, he observed, while possessing its own centre of attraction, will at the same time attract all the others; nay, "there must be somewhere in all the rows together the seat of a preponderating clustering power which will act upon all the stars in the neighbourhood" (Phil. Trans., vol. civ. p. 269). Speculations, indeed, upon the dynamical relations of "stars in rows," are still premature; nor are they likely, for some time to come, to be accounted as "of the order of the day." But the continual recurrence in the heavens of this mode of stellar aggregation cannot fail to suggest the development of plans of systemic dissolution and recomposition on too grand a scale to be other than vaguely apprehended by us.

The more attentively clusters are studied, the more intricate their construction appears to be. That which challenged Herschel's notice is not singular in exhibiting the federative union of a number of subordinate groups. There is rarely evidence, in the conformation of irregular clusters, of their being governed from a single focus of attraction; there are frequent indications of the simultaneous ascendancy of several. A cluster in Sagittarius ("G. C." 4335) is distinctly bifid. It was remarked by Sir John Herschel at Feldhausen as "divided by a broad, vacant, straight band" ("Cape Observations," p. 116). The fission (as in many nebulæ), no longer in the inchoate state of a "dark lane," is complete. Admiral Smyth's stellar "flight of wild ducks," in Sobieski's Shield (M 11), is perhaps trifid. Father Secchi, at least, perceived in it a three-lobed central vacuity (*Atti dell' Accad. Pont.*, t. vii. p. 75). Sir John Herschel, on the other hand, succeeded by the use of high powers, in breaking up "this glorious object" "into five or six distinct groups with rifts or cracks between them" (Phil. Trans., vol. cxxiii. p. 462). M. Helmert's measures of two hundred of its components referred to a ninth magnitude star conspicuous among them ("Publicationen der Hamburger Sternwarte," No. 1, 1874) will eventually afford the means of detecting their relative displacements. Several of them appear to be variable.

The disruptive tendency indicated by the peculiarities of their distribution is equally marked in "a reticulated mass of small stars" in Cygnus ("G. C." 4511), described at Parsonstown as "a most gorgeous cluster, *full of holes*." The figure published by Lord Rosse shows a winding ribbon of stars inclosing three blank circular spaces, of symmetrically diminishing diameters.

Star-groupings of curiously definite forms are often met with. A triangular swarm ("G. C." 5055) occurs in the tail of Cetus; a rectangular area in Vulpecula ("G. C." 4498) is densely strewn with fine star-dust. Clusters shaped like open fans are tolerably numerous. One situated in Gemini would appear, according to Sir John Herschel, if removed to a sufficient distance, "as a fan-shaped nebula with a bright point like a star at the vertex." Another specimen of an "acutangular" cluster ("G. C." 4902) is bounded by "two principal lines of stars drawing to one" (Phil. Trans., vol. cxxiii. pp. 476, 503). It is 2′ in length, and is to be found in the constellation Cepheus. An oval annulus of stars in Cygnus, 4′ across ("G. C." 4701), centrally surrounds a ruddy ninth magnitude star. A similar elliptical group, with a double substituted for the red star, constitutes a quasi-nucleus for the great cluster in Perseus ("G. C." 512). This superb object, like the still richer group it immediately precedes, has probably galactic affinities. The two together form a telescopic pageant such as, in the wildest flights of imagination, Hipparchus could little have dreamed would one day be unrolled before the eyes of men, out of the "cloudy spot" in the sword-handle of Perseus which he was the first (it is said) to detect. Although the outliers of the two clusters can be brought within the same field of view, they are believed to be really disconnected. The following, and more considerable (known as $\chi$ Persei) was micrometrically investigated by Vogel in 1867–70, photographically by O. Lohse in 1884 (*Astr. Nach.*, No. 2650). The result of the comparison of 172 stars was to show their complete immobility in an interval certainly too short for the visible development of such tardy movements as were alone likely to be in progress. A rapid spectroscopic survey executed by Vogel with the Berlin 9-inch refractor, March 30, 1876 ("Der Sternhaufen $\chi$ Persei," p. 31), disclosed nothing remarkable in the light of any of the clustered stars, although several of them have been called red, "pale garnet," and even "ruby." Their comparative brilliancy suggests that this magnificent assemblage, as well as its neighbour, may be less exorbitantly distant from the earth than most other objects of its class.

Red and double stars often—we are at a loss to imagine for what reason—seem to dominate in clusters. Compound objects must of course, through the chances of optical juxtaposition, occur most freely where stars are most crowded; yet when they are marked out (as often happens) both by superiority of lustre and by distinction of place, some significance may be attached to their presence. Thus, each of the oblique arms of a "cruciform" group in Auriga ("G. C." 1119), photographed at Paris on January 28, 1887, carries a pair of conjoined stars brighter than the rest (Smyth, "Cycle," p. 140). A "superb cluster" in Monoceros ("G. C." 1637), standing on a background of sky "singularly dotted over with infinitely minute points," has a double star in its most compressed part (J. Herschel, Phil. Trans., vol. cxxiii. p. 386). The central star in Præsepe is double; and there are many examples of more restricted groups gathered round a compound luminary.

Groups apparently ruled by a conspicuous ruddy star are met with in the constellations of the Swan ("G. C." 4676) and Auriga ("G. C." 1067). Another in Cygnus ("G. C." 4701) has already been mentioned.

The nebular affinities of stellar swarms are full of interest, but have as yet been very imperfectly investigated. The discoveries in the Pleiades, however, which may not prove to be the only cluster involved in cosmical fog-wreaths, show what can be done in this direction by the aid of photography. But since nebulæ thus situated are likely to be of the last degree of faintness, the stars probably replacing their original more brilliant knots, their existence can scarcely be made manifest otherwise than by prolonged exposures of plates of the highest sensitiveness. Visual detections of the kind will always be rare. Two rich clusters have nevertheless long been known to include each a nebula of the planetary kind. One in Argo ("G. C." 1801) has a central vacuity conspicuously occupied by a nebulous disk 40″ across; the other (M 46), not far from the head of Canis Major, displays well within its borders a fine annular nebula ("G. C." 1565). It is difficult, if not impossible, to believe either projected casually into such a very remarkable position.

The occurrence of *clusters within clusters* can just as little be set down to the account of chance. In one such instance, a large loose collection in Gemini ("G. C." 1490) involves a neat group of "six or seven stars close together, and well isolated from the rest" (Lord Rosse, Trans. R. Dublin Soc., vol. ii. p. 56). The companion example ("G. C." 1383) is found in the Milky Way, near Orion's right arm.

Researches into the mutual relations of clustered stars are still in their infancy. They will demand for their prosecution a reserve of patience as inexhaustible as the store of problems to be successively confronted. Before these come to an end, the human race itself will perhaps have become terrestrially extinct. But not, we may hope, before much has been attained that is well worth waiting and working for.

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